Ernest & Winders

Installation & Testing
Of a Storage Battery

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INSTALLATION AND TESTING OF A STORAGE BATTERY

BY

ROY ALFRED ERNEST
FRANK RAE WINDERS

Thesis for Degree of Bachelor of Science
in Electrical Engineering

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS

PRESENTED, JUNE, 1905

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Electrical Engineering.

Morgan Brooks

HEAD OF DEPARTMENT OF Electrical Engineering.

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I N T R O D U C T I O N .

As far as possible an attempt was made to make these tests commercial in character.

Our thanks are due to Mr. A. M. Dean of the Gould Storage Battery Company for many valuable suggestions regarding the tests.

The principal books comsulted in regard to the work were, "Storage Battery Engineering" by L. Lyndon and "Secondary Batteries their theory and Construction" by E. Wade.

C O N T E N T S.

D E S C R I P T I O N   O F   B A T T E R Y.

The storage battery installed in room 103 in the basement of the Electrical Engineering Labratory is made up of 60 cells placed in three rows as shown in diagram #4. The pedestal upon which the cells are placed are built of brick and covered with white glazed tile. The construction and dimensions of the pedestals are shown in diagram #2. Start- with cell #1 at the switch-board end of the battery there are in the outer row 10 end cells connected in series by means of re-inforced bus bars. The remainder of the row consists of 10 cells numbered from 11 to 20, in simple series connection. Returning to the switch-board end, the second row of cells is numbered from 21 to 40 away from the switch-board. This row is simply connected in a series. In the last row cells number toward the switch-board. Numbers 41 to 50 are connected in series, from 51 to 60 are arranged for connection either in series or multiple. This arrangement and numbering of cells was adopted in order to bring both end cells and multiple cells at the ends of the battery and to shorten as much as possible the connections to the switch-board.

The tanks are of one inch oak lined with 6 pound sheet lead. Details and dimensions of the tank and plates can be seen in diagram #2. Each tank contains three positive, two

negative and two half negative, Gould, type "O", plates, both positive and negative being of the Plante or formed type. The contact area of these plates is increased over the superficial area in a ratio of about 20 to 1 by process called scoring. The half negative used on the outside is scored only on one side and by this means weight, and cost of forming is reduced very materially. If new plates are added to this battery the half negative plates must be moved over to the outside of the cell. This, however, would be necessary even if a full negative were used, for the side of the negative which is not used would deteriorate very rapidly.

The tanks are each lined on four sides with glass plates which support the elements and prevent them from touching the lead lining and causing short circuits. The plates are insulated from each other by glass rods which are held in place at the bottom of the tanks by lead troughs and at the top by rubber spacers and projections on the plates..

INSTALLATION.

After washing the tanks, examining them for leaks and mending a few broken ones they were assembled on white porcelain insulators placed on top of supporting strips which in turn rest upon rows of tile cemented to the tops of the pedestals. The space between the multiple cells is 1 1/8 inches and between all the rest of the cells 5/8 of an inch. The plates were straightened by pounding lightly between two flat surfaces and the lugs sawed off and scraped bright to facilitate burning to the bus bars. The plates were then placed in the tanks, the lugs burned to the bus bars by means of the oxy-hydrogen flame and the glass insulators put in place. The electrolyte was put in at a density of about 1.211 and the battery placed on charge at 60 amperes.

The charge was run in all 86 hours; 16 1/2 hours at 60 amperes, 7 hours at 45 amperes and 36 hours at 30 amperes. The gassing and overcharge had by this time brought the electrolyte density up to about 1.216. It was brought down by means of distilled water to about 1.210 at the end of charge. In order to distribute this water through the cells and to avoid local action due to different electrolyte density in different parts of the cell the battery was placed on charge at 30 amperes for 2 1/2 hours. The input during this charge was in all 3022 ampere hours or 318.5 kilo-watt hours; more

than 12 times the normal capacity of the battery. All but 220 ampere hours of this energy was thrown away in gassing and reducing the sulphate.

TESTING.

Only 40 of the cells were used in these tests because the bus bars for the other 20 were late in arriving. Two sets of tests were run,each set consisting of five charges and discharges. The charges were all made at the 30 ampere rate and the discharges at 30, 45, 60, 75 and 100 amperes respectively. The batteries were not allowed to stand discharged and in each case the discharge was made as soon as possible after the charge was finished. When the discharge could not be immediately started the battery was placed on charge for a few moments at 30 amperes immediately before discharge was started in order to bring the pressure up to 104 volts and make the basis of comparison a fair one.

In every case the battery was charged up to 104 volts, or 2.6 volts per cell and discharged down to 72 volts or 1.8 volts per cell. The leakage when the battery was standing fully charged was inappreciable. The battery was fully charged and allowed to stand for several days. When again placed on charge at 30 amperes the pressure immediately came up to 104 volts. The power for charging was taken from a shunt generator run with no other load, by motor. This gave wide voltage regulation both by speed variation and rheostatic control of the motor field. A recording volt meter was used but check readings were taken at frequent intervals. The dis-

charges were made through lamp banks and resistances of german silver and iron strips.

Charge at 30 amperes.
Discharge at 30 amperes.

The charging was all done at 30 amperes. After the initial charge was finished the battery was discharged at the normal rate. It was immediately recharged at 30 amperes and the input was 240 ampere hours or 21905 watt hours. This value was assumed , in figuring efficiencies, to be the full capacity of the battery. It was necessary to use this plan on account of the recovery of the battery after discharge at a high rate. In order to compare each input and output it would have been necessary after each discharge to allow the battery to recover and then complete the discharge at the normal rate. On account of the time involved this method was not used.

The maker's rating at the 30 ampere discharge rate was 240 ampere hours. The test showed only 206.5 ampere hours or only 86.0% of rated capacity. The tendency in a new battery is for the effeciency to increase for a time. The second set of readings in this case showed a uniformly lower effeciency than the first set so with this battery it can hardly be hoped that there will be any marked increase of effeciency.

45 ampere discharge.

The company's rating for the five hour discharge is

42 amperes. At this rate the capacity should be 210 ampere hours. The test showed 185.9 ampere hours at the 45 ampere rate. This is about 88% of the rated capacity. The discharge lasted 3.8 hours.

60 ampere discharge.

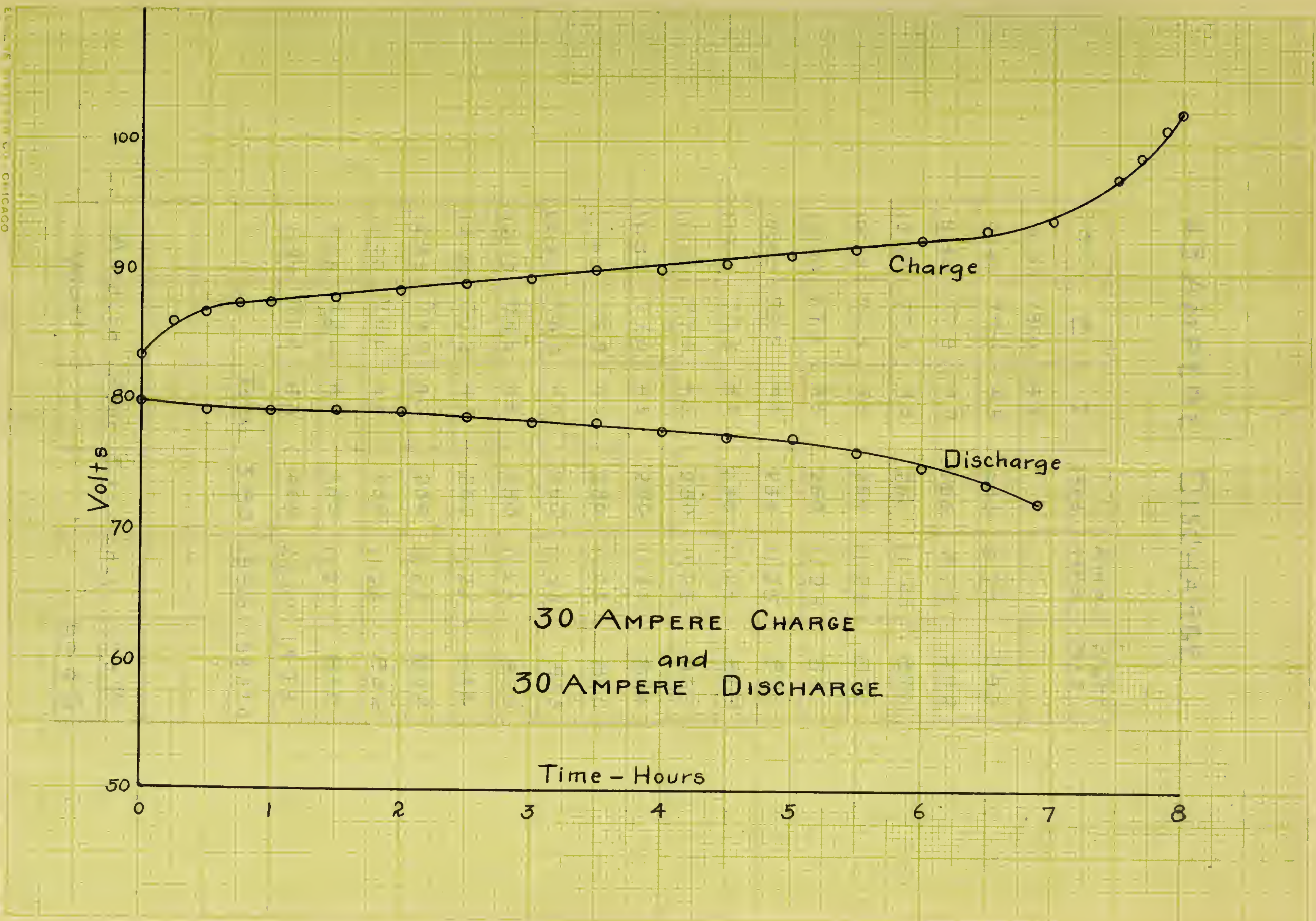
The company's rating for the three hour discharge is 60 amperes. At this rate the capacity should be 180 ampere hours. The test showed 160 ampere homrs or 88.8% of the rating. The discharge lasted 2.66. For this type of cell the bulletins give no ratings for 75 and 100 ampere rates of discharge.

30 Ampere Charge

T	E	I	Hrs.	Amp. Hrs.	Watt Hrs.
4:05	83.0	30			
4:15	86.5	30	.166	5.0	421
4:30	87.0	30	.250	7.5	652
4:45	87.4	30	.250	7.5	655
5:00	87.9	30	.250	7.5	659
5:30	88.2	30	.500	15.0	1323
6:00	88.6	30	.500	15.0	1329
6:30	89.0	30	.500	15.0	1335
7:00	89.0	30	.500	15.0	1335
7:30	90.0	30	.500	15.0	1350
8:00	90.0	30	.500	15.0	1350
8:30	90.5	30	.500	15.0	1357
9:00	91.0	30	.500	15.0	1365
9:30	91.5	30	.500	15.0	1372
10:00	92.5	30	.500	15.0	1387
10:30	93.0	30	.500	15.0	1395
11:00	94.0	30	.500	15.0	1410
11:30	97.0	30	.500	15.0	1455
11:45	98.5	30	.250	7.5	738
11:55	101.0	30	.166	5.0	505
12:00	102.0	30	.083	2.5	255
12:05	103.0	30	.083	2.5	257
Total			8.00	240.0	21905.0

30 Ampere Discharge

T	E	I	Hrs.	Amp. Hrs.	Watt Hrs.
10:55	79.5	30			
11:00	79.0	30	.083	2.5	199
11:30	79.0	30	.500	15.0	1184
12:00	79.0	30	.500	15.0	1184
12:30	79.0	30	.500	15.0	1184
1:00	78.5	30	.500	15.0	1179
1:30	78.0	30	.500	15.0	1170
2:00	78.0	30	.500	15.0	1170
2:30	77.5	30	.500	15.0	1162
3:00	77.0	30	.500	15.0	1157
3:30	76.8	30	.500	15.0	1152
4:00	76.5	30	.500	15.0	1148
4:30	75.7	30	.500	15.0	1138
5:00	74.6	30	.500	15.0	1119
5:15	74.1	30	.250	7.5	555
5:30	73.2	30	.250	7.5	544
5:42	72.2	30	.200	6.0	433
5:48	72.0	30	.100	3.0	216
		Total	6.88	206.5	15904.0
Ampere Hour Efficiency					86.0 %
Watt		"	"		72.5 %


30 AMPERE CHARGE
and
30 AMPERE DISCHARGE
Charge
Discharge
Volts
100
90
80
70
60
50
Time - Hours
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3
4
5
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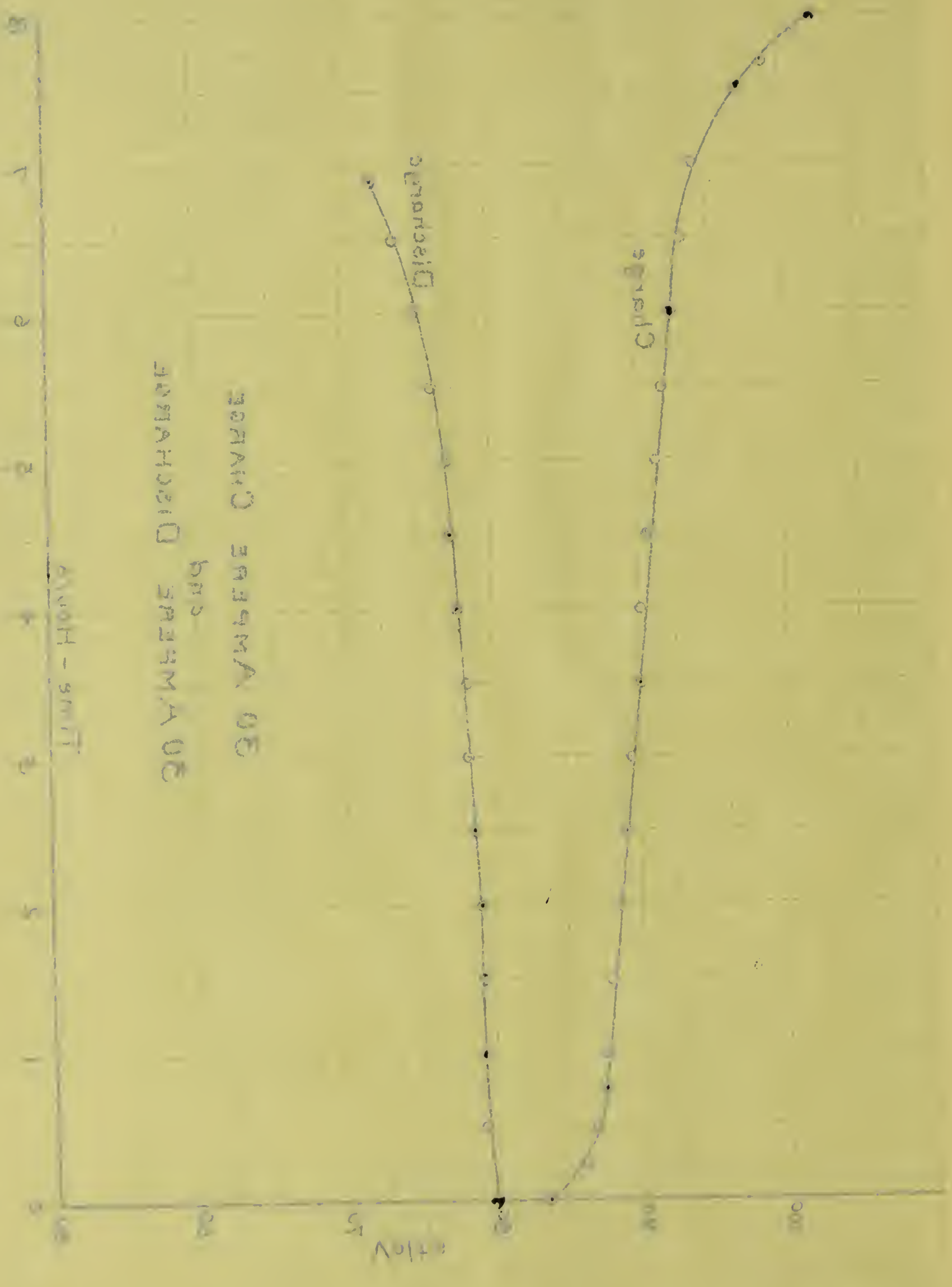
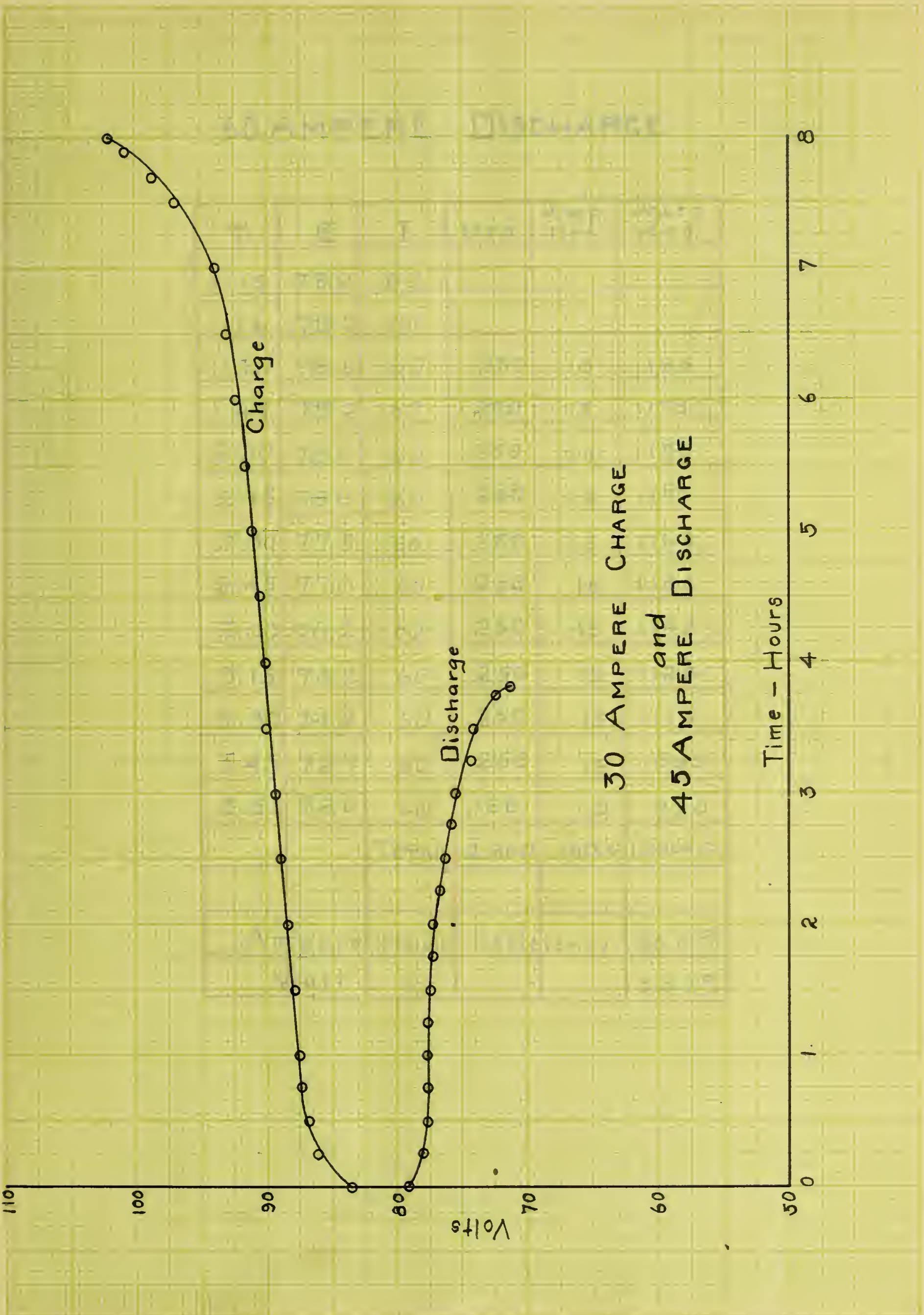
7
8


30 Ampere Charge
and
30 Ampere Discharge
Charge
Discharge
Volts
Time - Hours

45 AMPERE DISCHARGE

T	E	I	Hrs.	Amp. Hrs.	Watt Hrs.
9:35	79.0	45			
9:40	77.9	45	.083	3.73	292
9:45	77.9	45	.083	3.73	292
10:00	77.5	45	.250	11.25	871
10:15	77.5	45	.250	11.25	871
10:30	77.5	45	.250	11.25	871
10:45	77.5	45	.250	11.25	871
11:00	77.3	45	.250	11.25	869
11:15	77.0	45	.250	11.25	866
11:30	77.0	45	.250	11.25	866
11:45	76.5	45	.250	11.25	860
12:00	76.0	45	.250	11.25	855
12:15	75.6	45	.250	11.25	850
12:30	75.2	45	.250	11.25	846
12:45	74.0	45	.250	11.25	832
1:00	74.0	45	.250	11.25	832
1:15	72.0	45	.250	11.25	810
1:26	71.2	45	.466	20.97	1473
		TOTAL	3.80	185.9	13927.0
Ampere		Hour	Efficiency		77.5 %
Watt		"	"		63.5 %


30 Ampere Charge
and
45 Ampere Discharge
Charge
Discharge
Volts
Time – Hours
110
100
90
80
70
60
50
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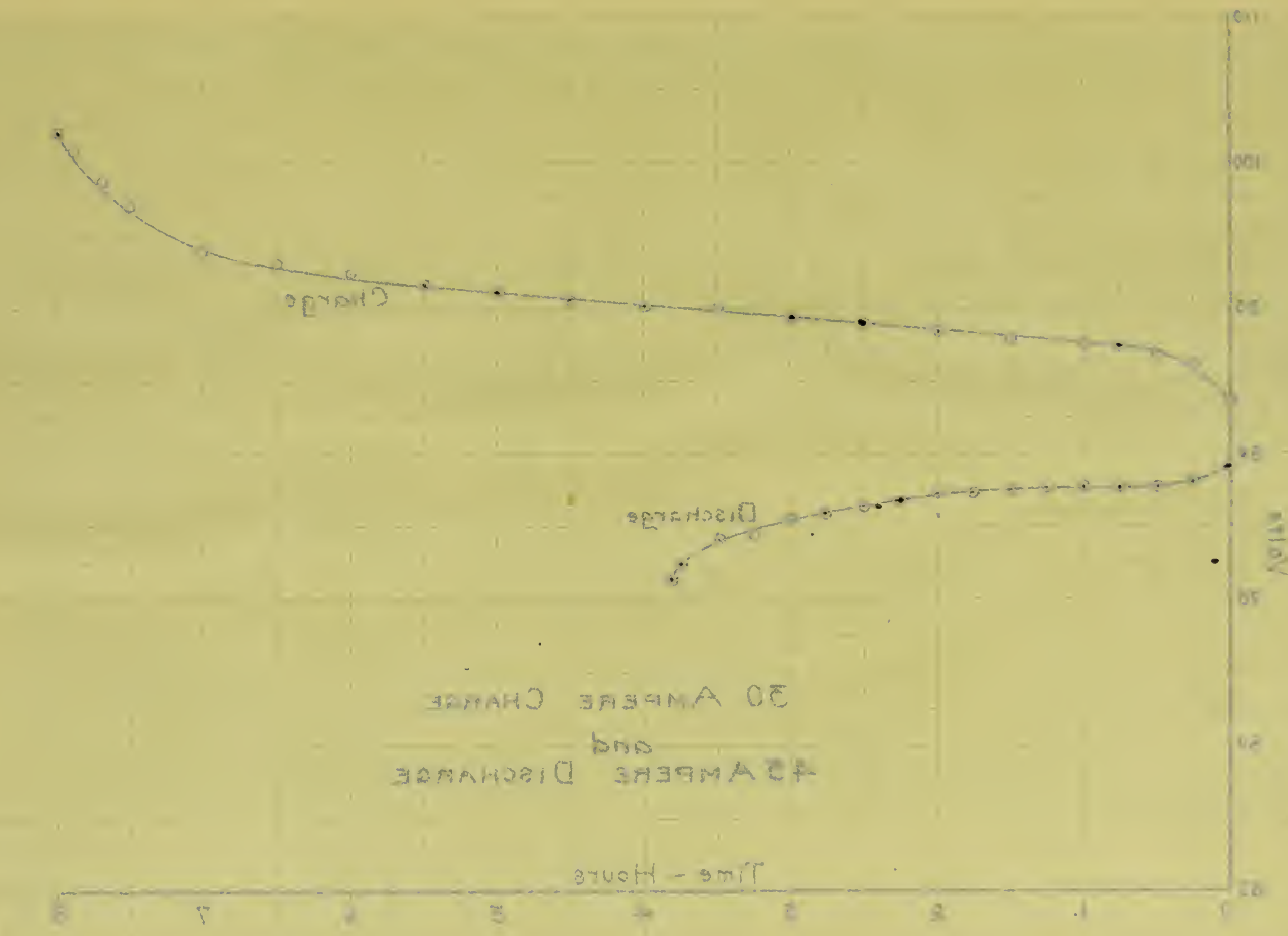
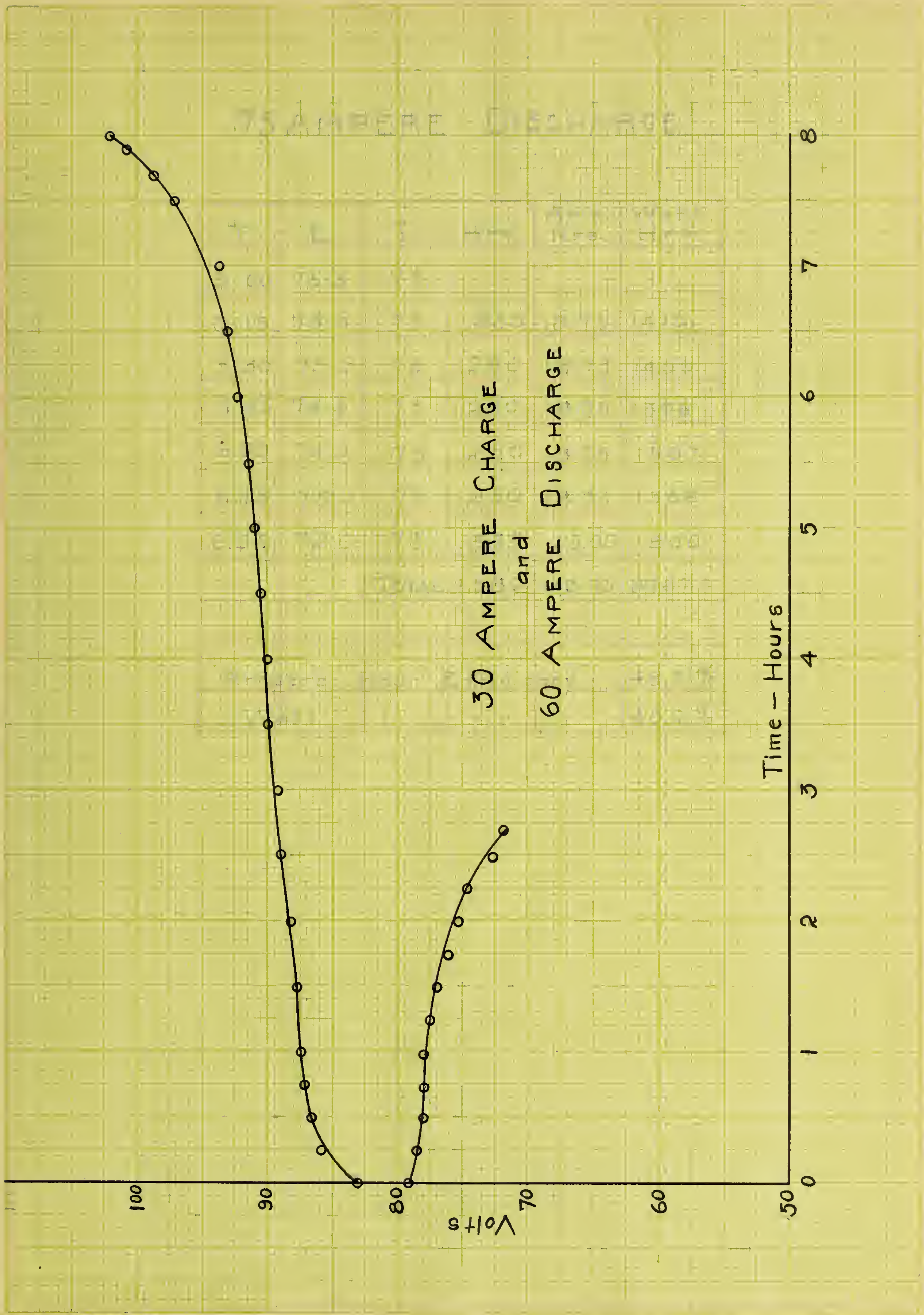
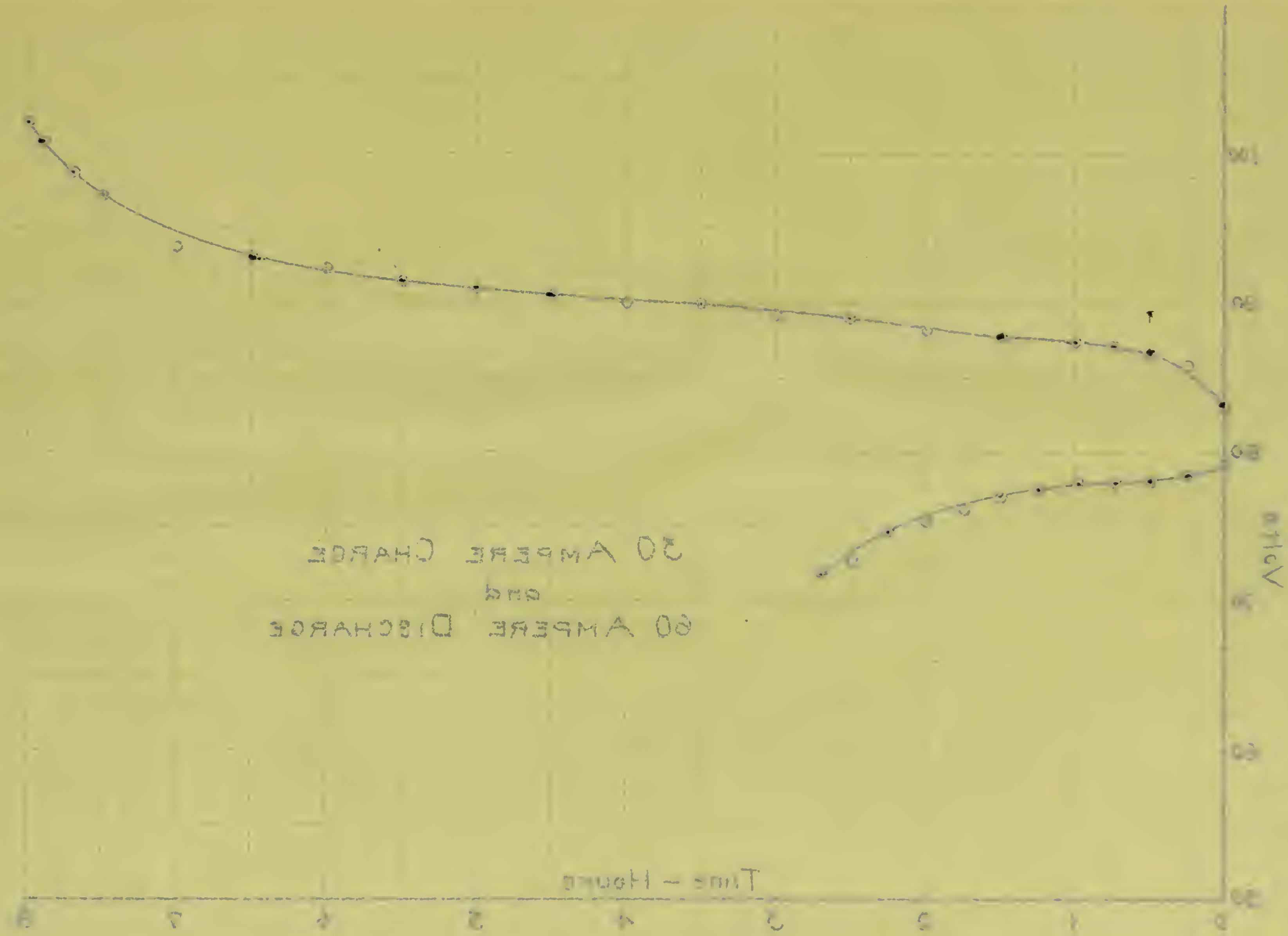
3
4
5
6
7
8


30 AMPERE CHARGE
and
45 AMPERE DISCHARGE
Charge
Discharge
Time - Hours
Volts

60 Ampere Discharge

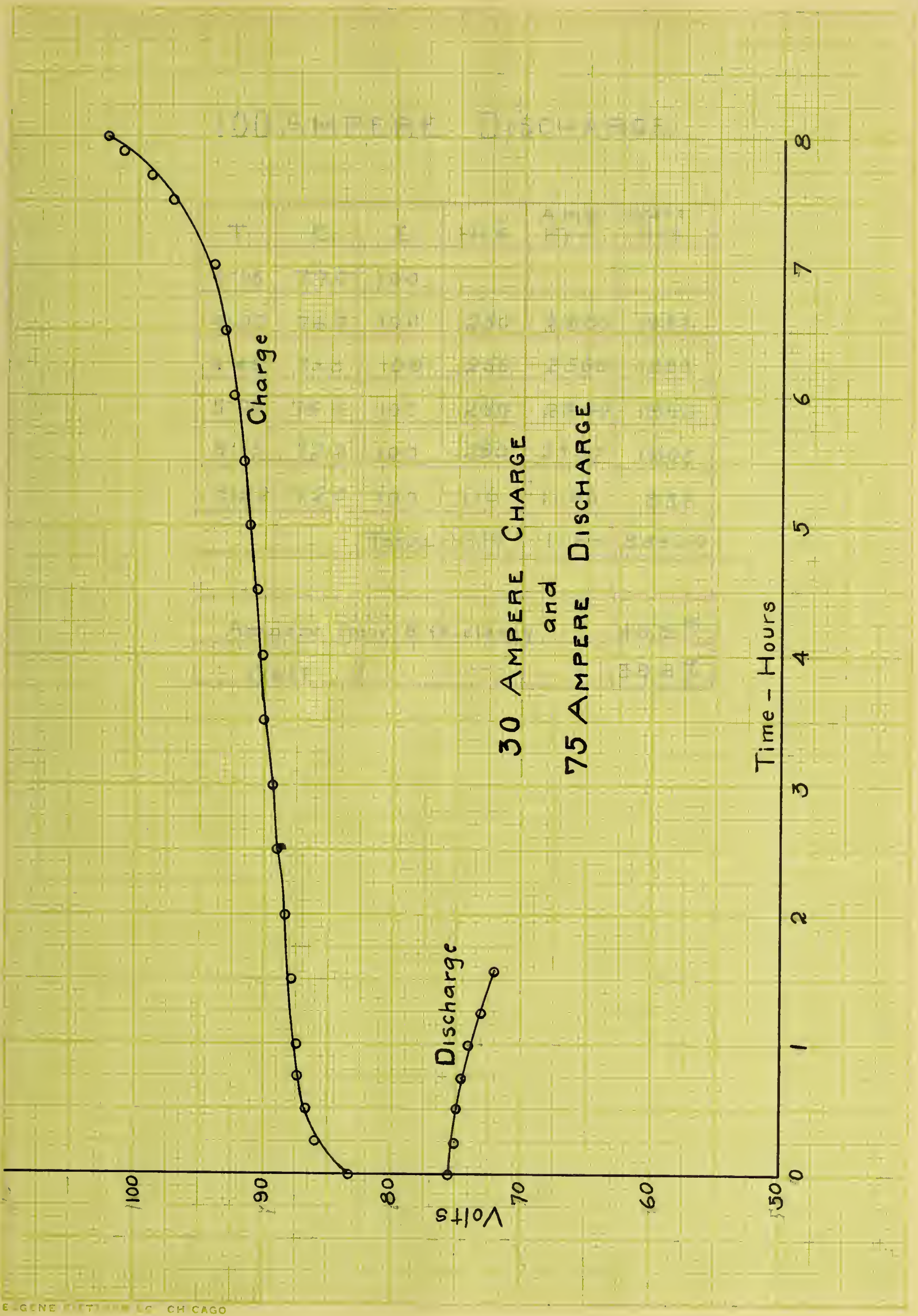
T	E	I	Hrs.	Amp. Hrs.	Watt Hrs.
1:15	79.2	60			
1:16	79.0	60			
1:30	78.5	60	.250	15	1183
1:45	78.2	60	.250	15	1173
2:00	78.0	60	.250	15	1170
2:15	78.0	60	.250	15	1170
2:30	77.5	60	.250	15	1162
2:45	77.0	60	.250	15	1155
3:00	76.2	60	.250	15	1143
3:15	75.2	60	.250	15	1128
3:30	74.2	60	.250	15	1113
3:45	72.7	60	.250	15	1090
3:55	72.0	60	.166	10	720
		Total	2.660	160.0	12204.0
Ampere		Hour	Efficiency		66.6 %
Watt		"	"		55.7 %


30 Ampere Charge
and
60 Ampere Discharge
Time – Hours
Volts
0
1
2
3
4
5
6
7
8
50
60
70
80
90
100


30 Ampere Charge
and
60 Ampere Discharge
Time – Hours
Volts

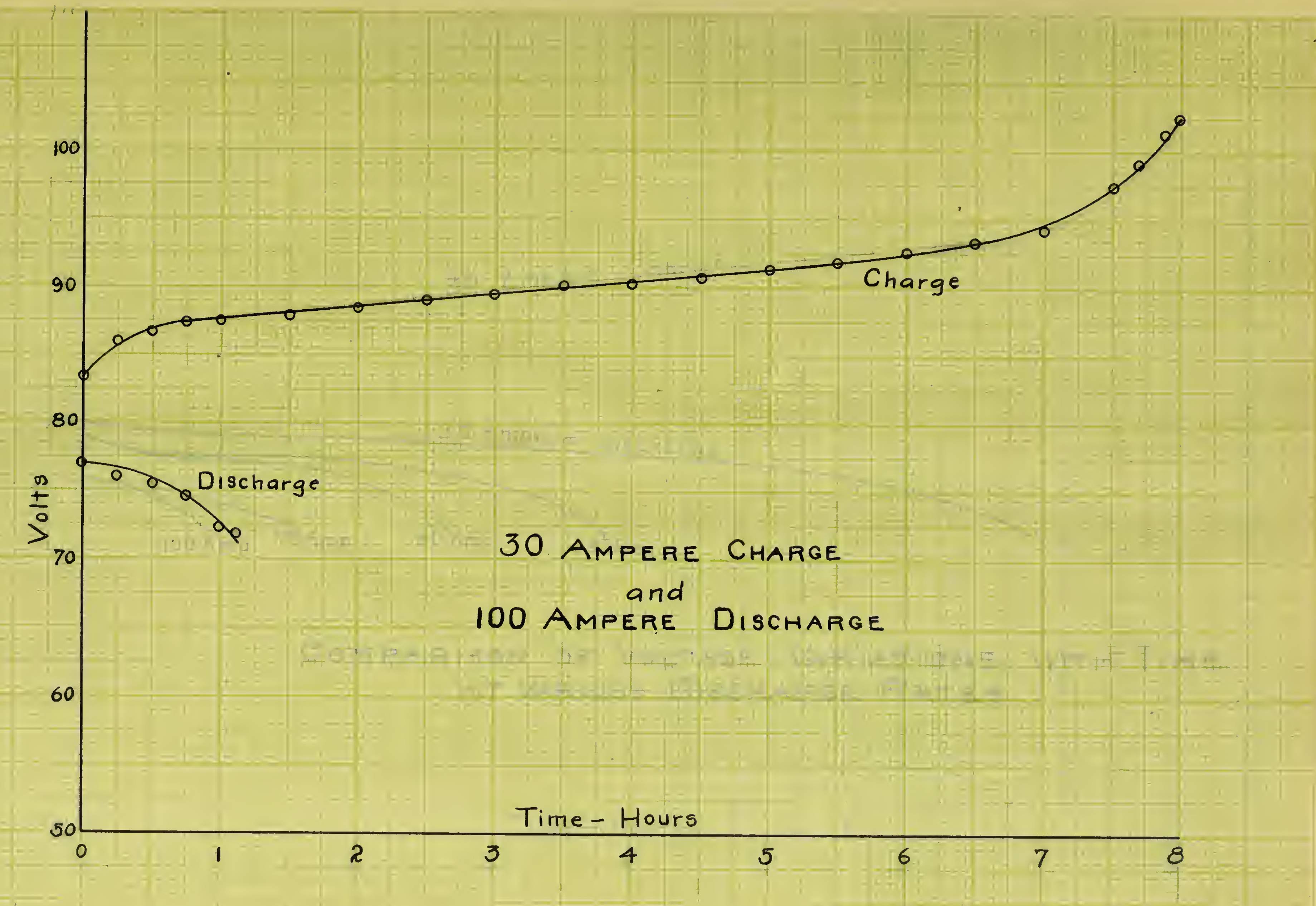
75 Ampere Discharge

T	E	I	Hrs.	Amp. Hrs.	Watt Hrs.
5:00	75.5	75			
5:15	75.0	75	.250	18.75	1410
5:30	75.0	75	.250	18.75	1406
5:45	74.5	75	.250	18.75	1396
6:00	74.0	75	.250	18.75	1387
6:15	73.0	75	.250	18.75	1368
6:35	72.0	75	.333	25.00	1800
		Total	1.580	118.75	8767.0
Ampere	Hour	Efficiency			49.5 %
Watt		"	"		40.0 %

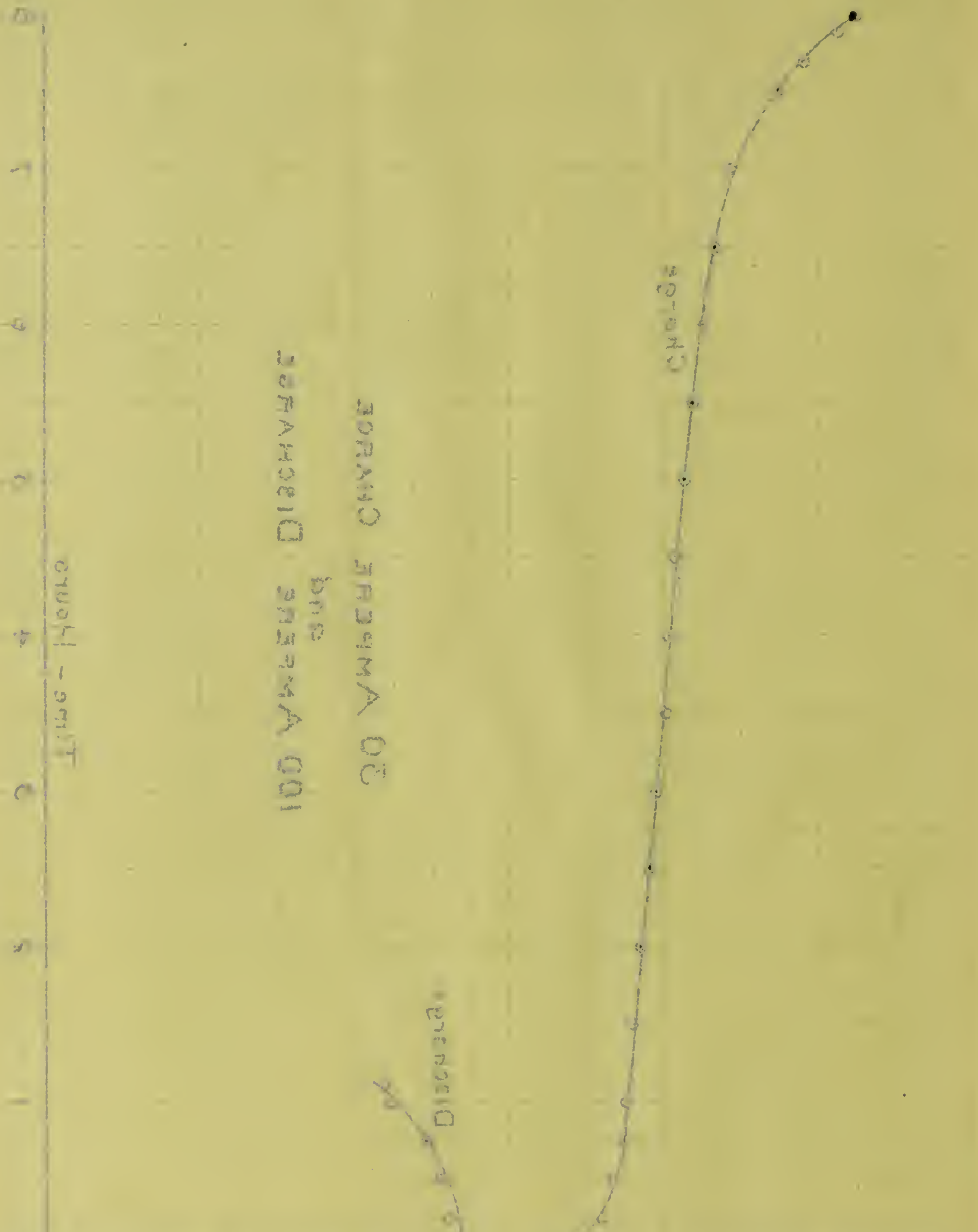

30 Ampere Charge
and
75 Ampere Discharge
Charge
Discharge
Volts
Time - Hours
100
90
80
70
60
50
0
1
2
3
4
5
6
7
8

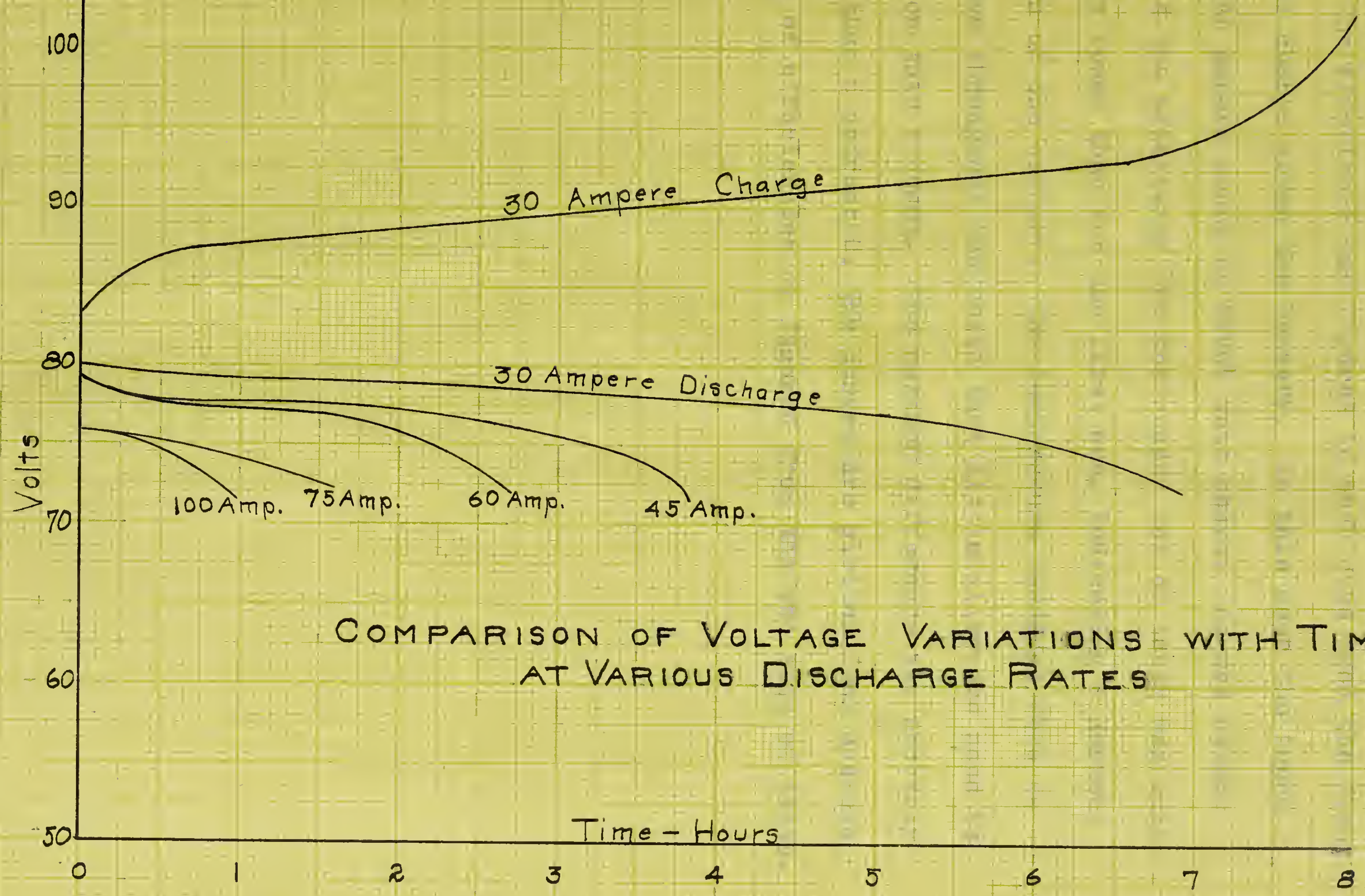
100 Ampere Discharge

T	E	I	Hrs.	Amp. Hrs.	Watt Hrs.
4:15	77.0	100			
4:30	76.0	100	.250	25.00	1937
4:45	75.5	100	.250	25.00	1900
5:00	74.6	100	.250	25.00	1865
5:15	72.2	100	.250	25.00	1805
5:22	72.0	100	.116	11.66	835
		Total	1.116	111.66	8342.0
Ampere Hour Efficiency					46.5 %
Watt " "					38.8 %



EUGENE DIETZGEN CO. CHICAGO


30 AMPERE CHARGE
and
100 AMPERE DISCHARGE
Time - Hours
Volts
Charge
Discharge



COMPARISON OF VOLTAGE VARIATIONS WITH TIME AT VARIOUS DISCHARGE RATES

EUGENE DIETZGEN CO., CHICAGO

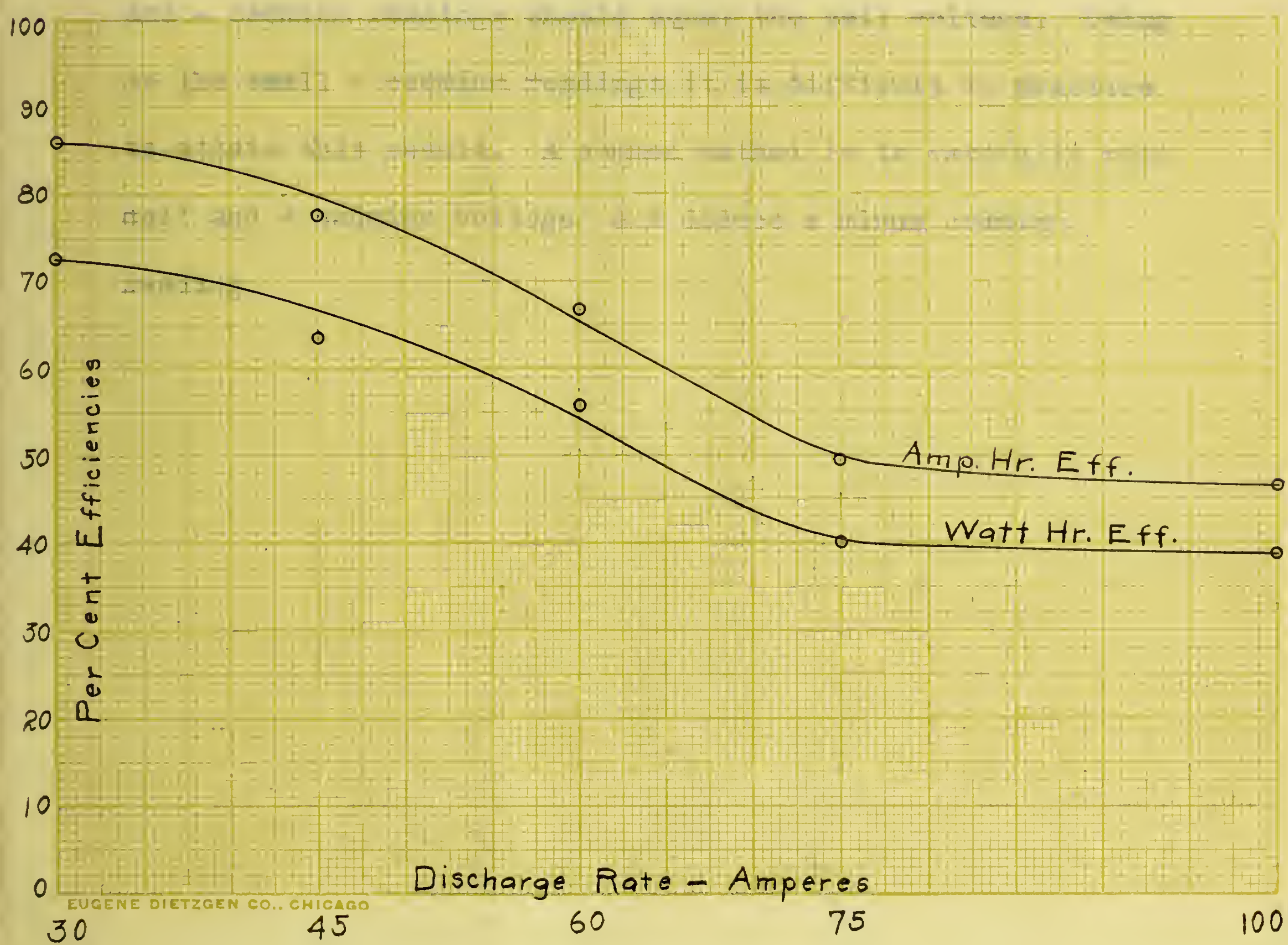
Variation of effeciency with rate of discharge.

The effeciency was figured in each case from the first normal charge given the battery. In this case the input was 240 ampere hours or 21905 watt hours. As was before stated the effeciency for the second set of tests was uniformly lower than for the first one, indicating a depreciation of the battery. The temperature readings were so uniform throughout the tests that little allowance need be made on this account. The maximum difference was probably less than 5 defrees C. The curves are plotted from average value of effeciencies as figured from the two sets of tests.

Variation of Efficiency with Rate of Discharge

Rate	Ampere Hr. Efficiency %	Watt Hr. Efficiency %
30 Amp.	86.0	72.5
45 "	77.5	63.5
60 "	66.6	55.7
75 "	49.5	40.0
100 "	46.5	38.8

Variation of Efficiency with Rate of Discharge



Variation of cadmium readings with charge and discharge.

Cadmium readings were taken every half hour during charge and discharge. The algebraic sum of the + cadmium and - cadmium readings should equal the cell voltage. Owing to the small - cadmium readings it is difficult in practice to attain this result. A common method is to carefully read cell and + cadmium voltage and deduce a minus cadmium reading.

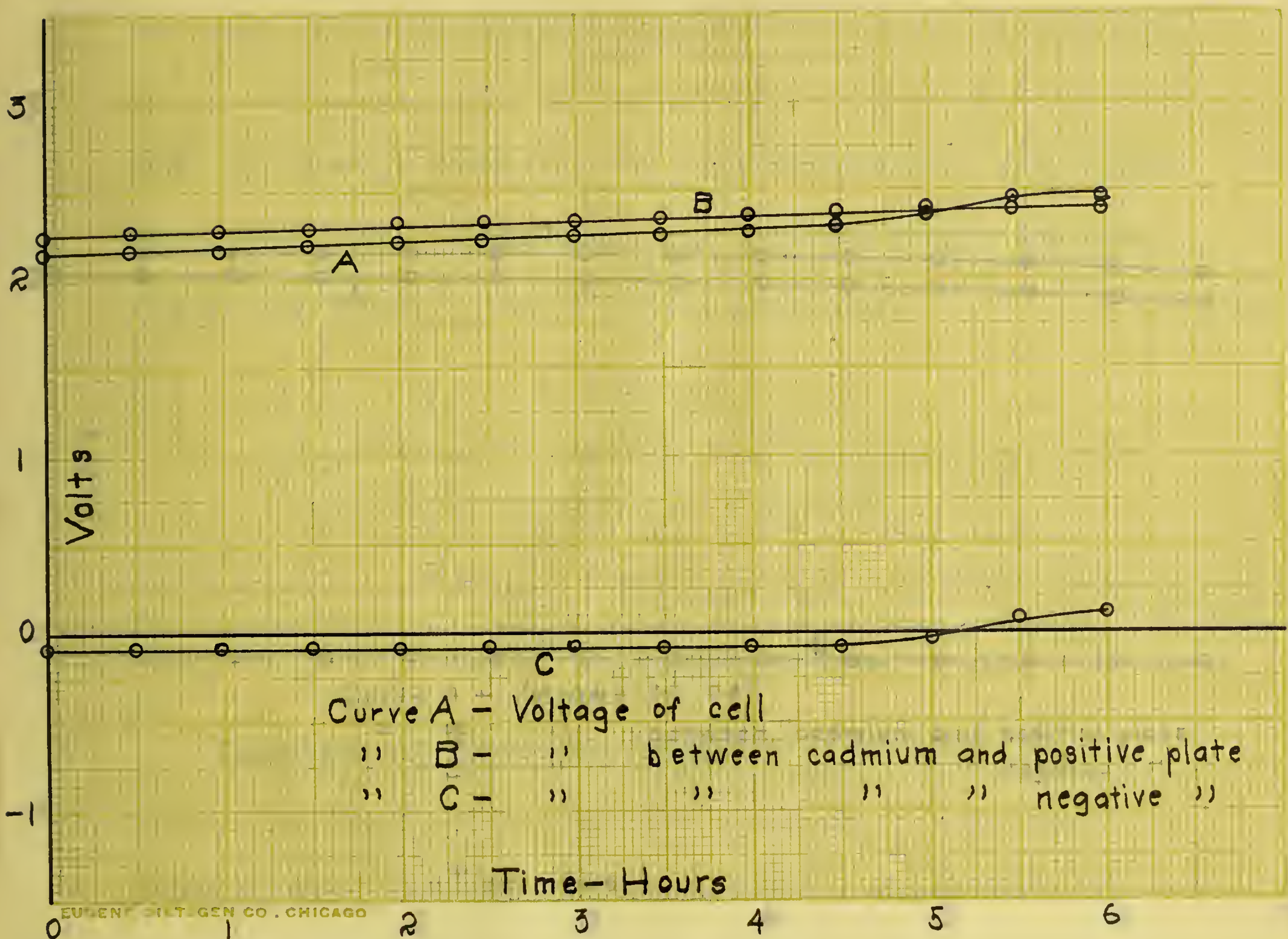
Variation of Cadmium Readings during 30 Ampere Charge

T	+ Cd.	− Cd.	Cell
1:00	2.24	−.102	2.14
1:30	2.26	−.116	2.15
2:00	2.26	−.113	2.16
2:30	2.27	−.116	2.17
3:00	2.30	−.120	2.20
3:30	2.31	−.120	2.20
4:00	2.32	−.120	2.23
4:30	2.32	−.120	2.23
5:00	2.34	−.113	2.25
5:30	2.34	−.110	2.26
6:00	2.36	−.090	2.29
6:30	2.36	−.010	2.42
7:00	2.37	+.111	2.42

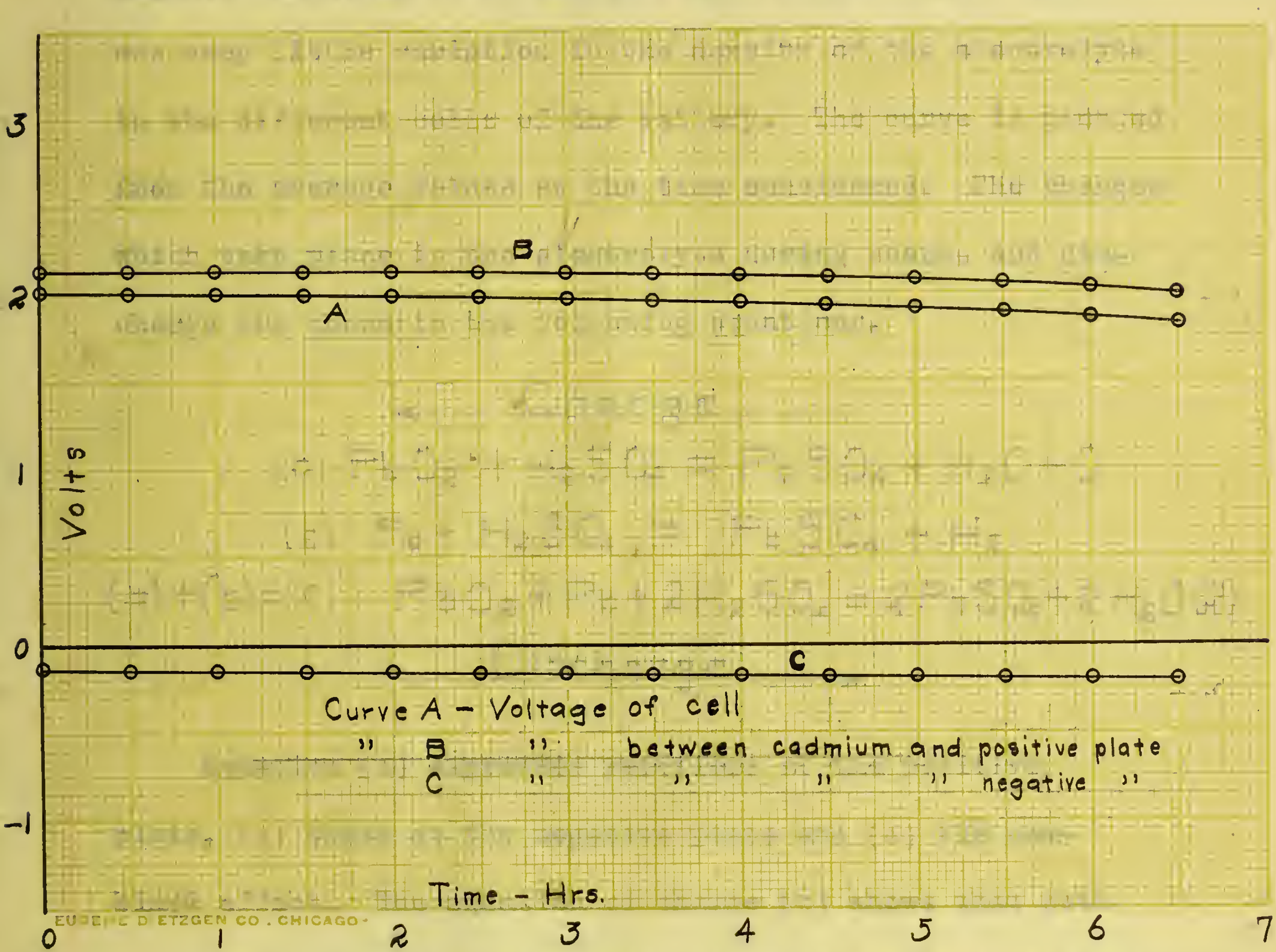
Variation of Cadmium Readings during 30 Ampere Discharge

T	+ Cd.	− Cd.	Cell
5:30	2.130	−.130	2.01
6:00	2.130	−.146	2.00
6:30	2.130	−.150	2.00
7:00	2.120	−.149	1.99
7:30	2.120	−.149	1.99
8:00	2.110	−.149	1.97
8:30	2.110	−.160	1.96
9:00	2.086	−.166	1.95
9:30	2.070	−.166	1.94
10:00	2.066	−.172	1.92
10:30	2.061	−.176	1.91
11:00	2.050	−.185	1.89
11:30	2.027	−.190	1.86
12:00	2.000	−.195	1.82

VARIATION OF CADMIUM READINGS during 30 AMPERE CHARGE



Variation of Cadmium Readings during 30 Ampere Discharge



Specific Gravity Variation.

The quantity of electrolyte in the cell is more than double the necessary amount owing to the extra space left for enlarging the battery. This causes the electrolyte density variation to be somewhat less than normal. There was very little variation in the density of the electrolyte in the different cells of the battery. The curve is plotted from the average values at the time considered. The changes which take place in the electrolyte during charge and discharge are shown in the following equations.

$$\xleftarrow{\text{Charge}}$$

$$(a)\quad PbO_2 + H_2SO_4 = PbSO_4 + H_2O + O$$

$$(b)\quad Pb + H_2SO_4 = PbSO_4 + H_2$$

$$(a)+(b)=(c)\quad PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O \quad (2)$$

$$\xrightarrow[\text{Discharge}]{}$$

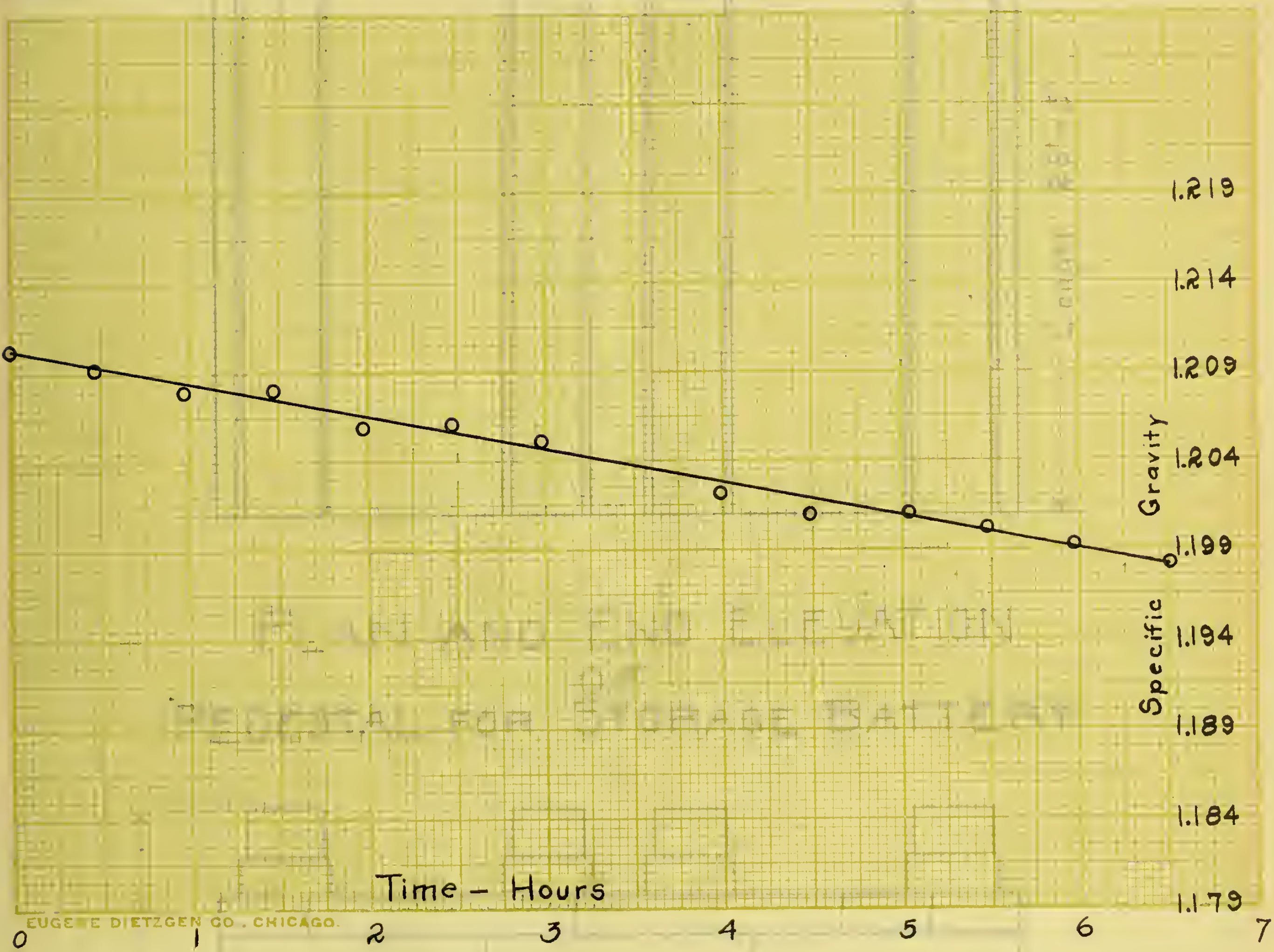
Equation (a) expresses reactions at the positive plate, (b) those at the negative plate and (c) the combined effect. The equation of charge (c) shows that both negative and positive electrodes start as lead sulphate and combiningwith the dissociated gases of the water in the electrolyte, they turn into lead and lead peroxide respectively. Also SO_3 is released which combining with the water in the electrolyte, forms sulphuric acid. Read from left to right it is the equation of discharge and shows the changes

of lead and lead peroxide on the negative and positive plates respectively into lead sulphate and the reduction of sulphuric acid to water.

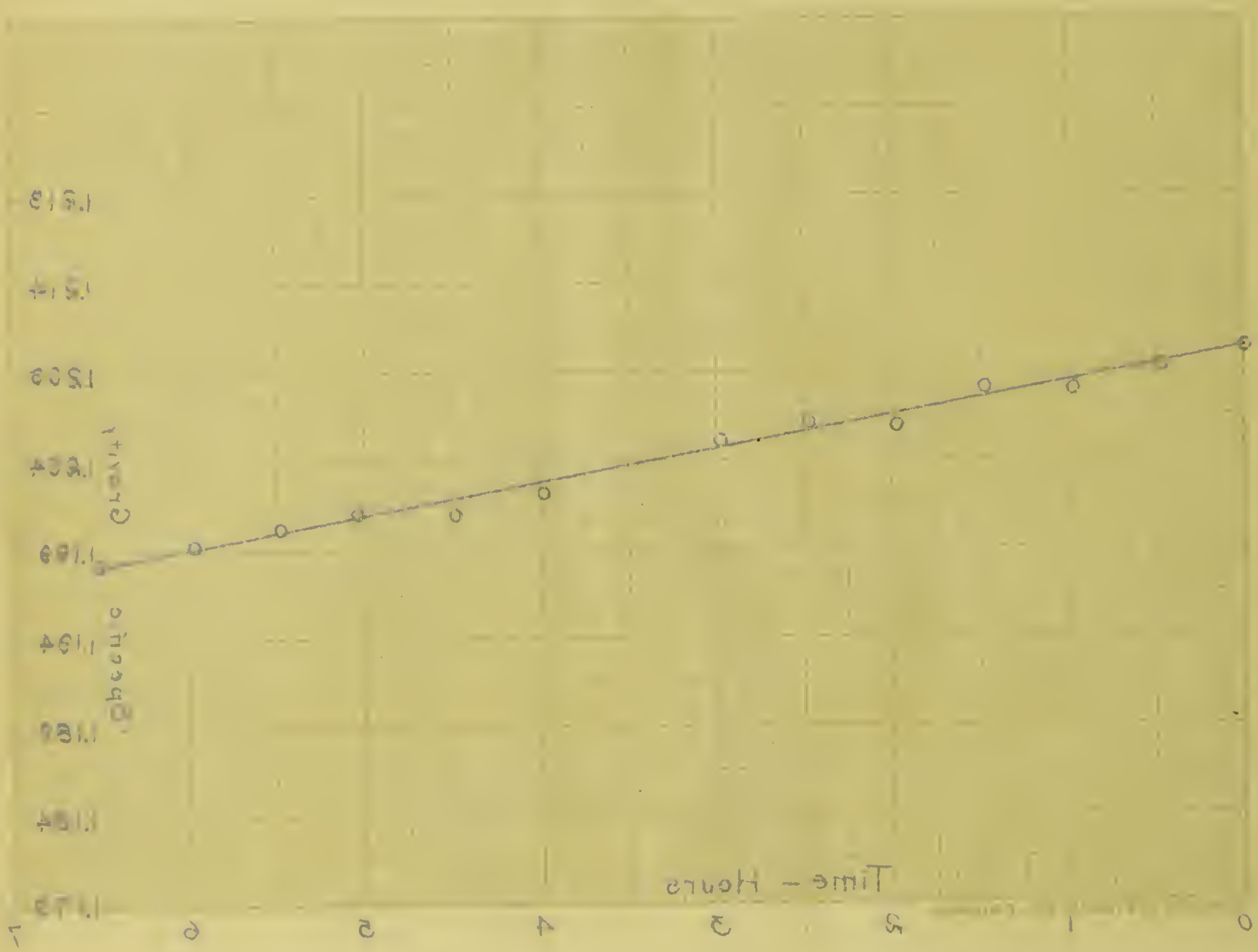
Specific Gravity Variation

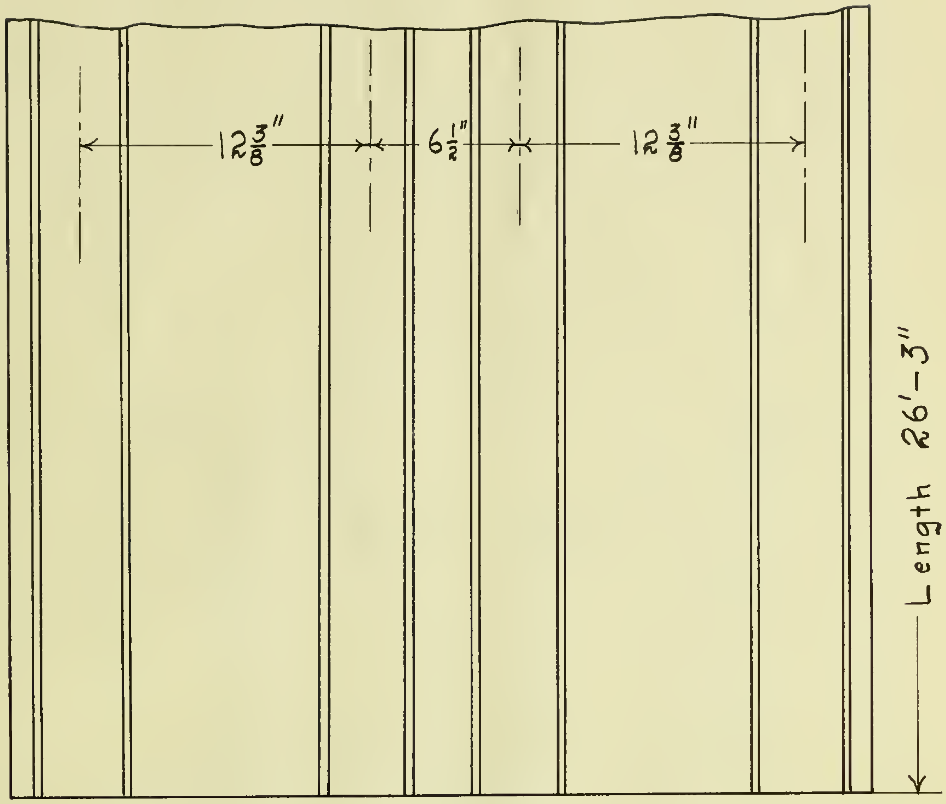
Discharge		Charge	
T	Specific Gravity Cor. to 25°C.	T	Specific Gravity Cor. to 25°C.
5:30	1.210	1:00	1.197
6:00	1.209	1:30	1.199
6:30	1.208	2:00	1.199
7:00	1.207	2:30	1.200
7:30	1.206	3:00	1.200
8:00	1.206	3:30	1.201
8:30	1.205	4:00	1.202
9:00	1.203	4:30	1.202
9:30	1.202	5:00	1.203
10:00	1.201	5:30	1.204
10:30	1.200	6:00	1.205
11:00	1.200	6:30	1.211
11:30	1.199	7:00	1.212
12:00	1.198		

Variation of Electrolyte Density during 30 Ampere Discharge



VARIATION OF ELECTROLYTE DENSITY during 30 AMPERE DISCHARGE





PLAN AND END ELEVATION
OF
PEDESTAL FOR STORAGE BATTERY

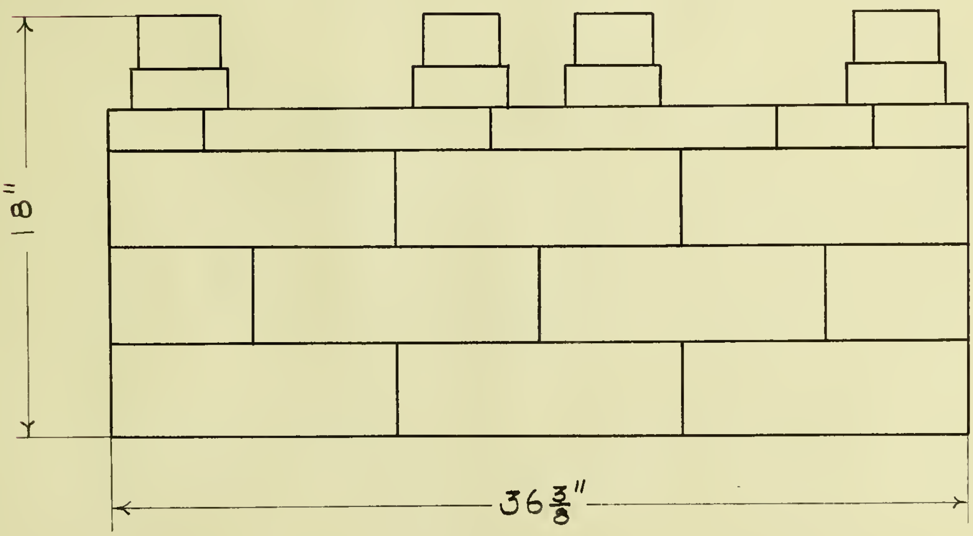


Fig. 2.

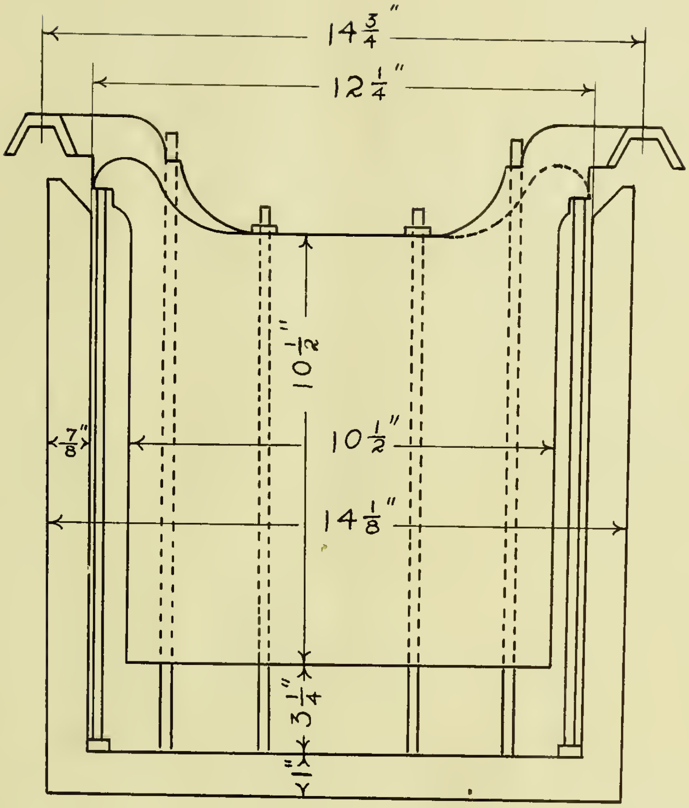
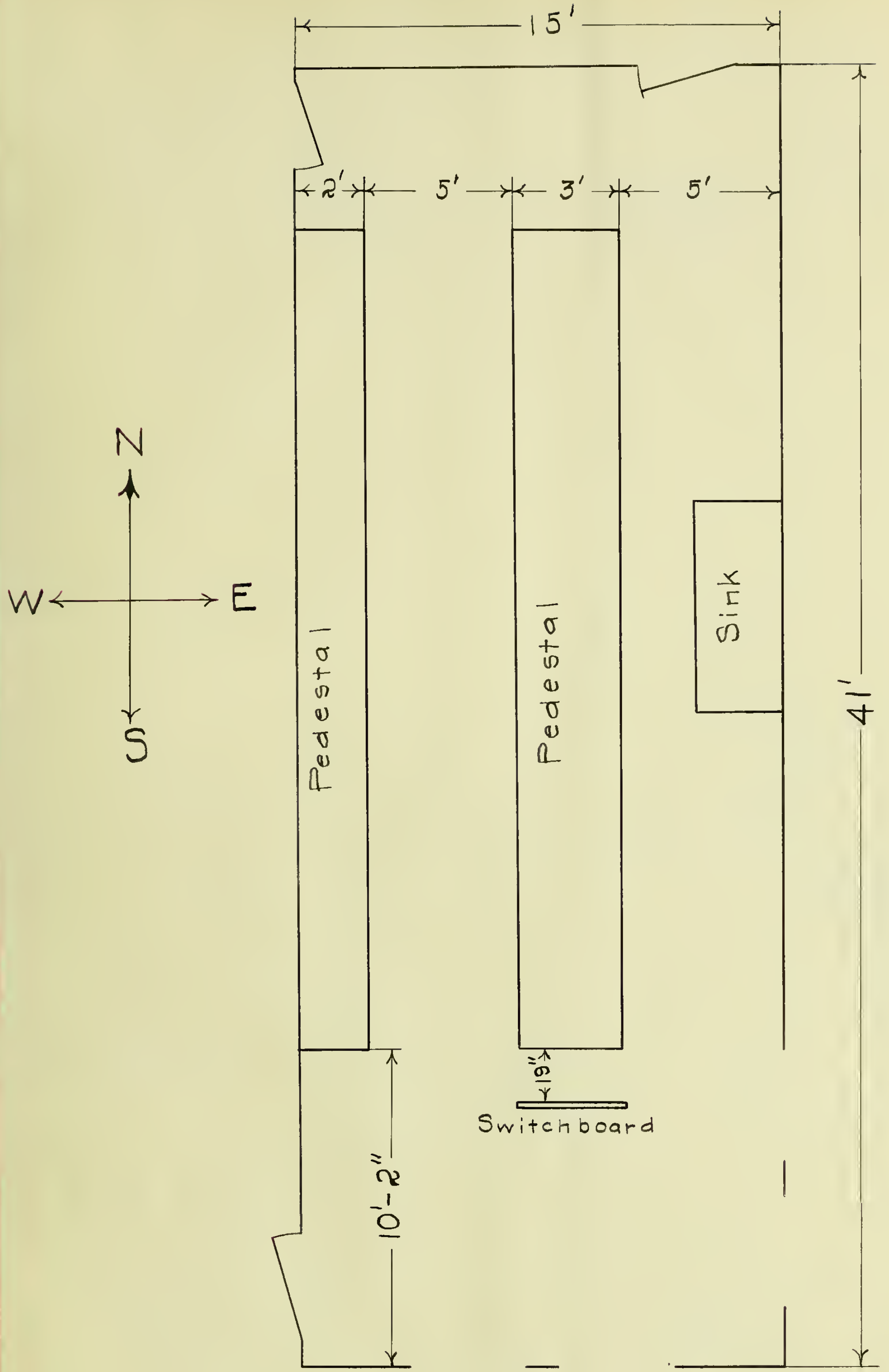


Fig. 3.

Sectional View of Cell



PLAN OF STORAGE BATTERY ROOM

Fig. 1.

WIRING DIAGRAM
FOR
STORAGE BATTERY
PANEL
E.E. DEPT. U. OF I. MAY 1905
ERNEST and WINDERS

Fig. 4.

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